Predicting the Evolution of Shallow Cumulus Clouds with a Lotka-Volterra-like Model

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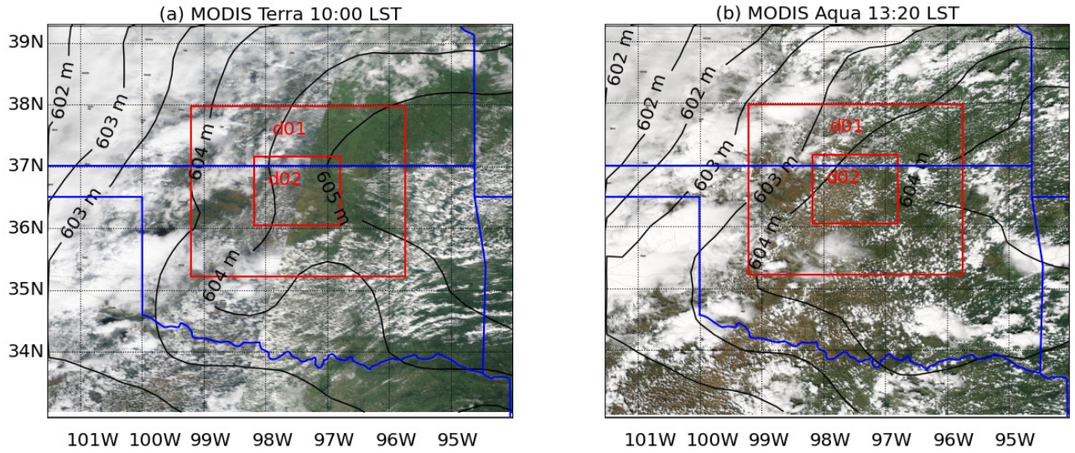
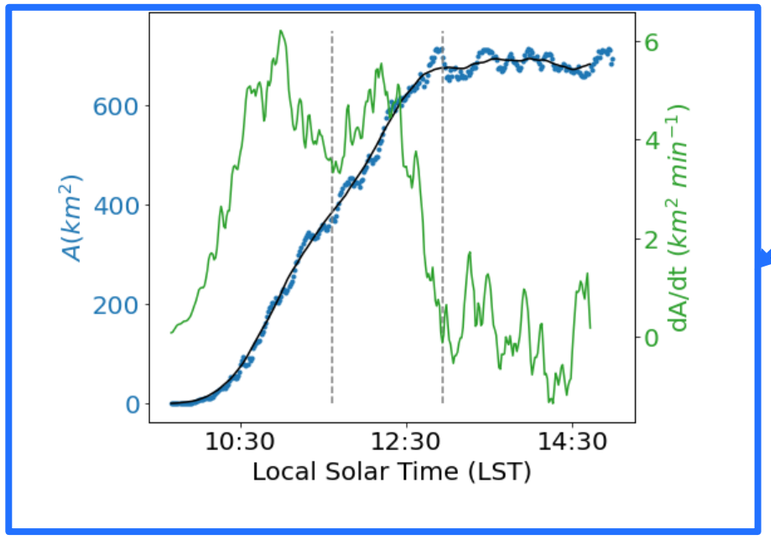
Introduction

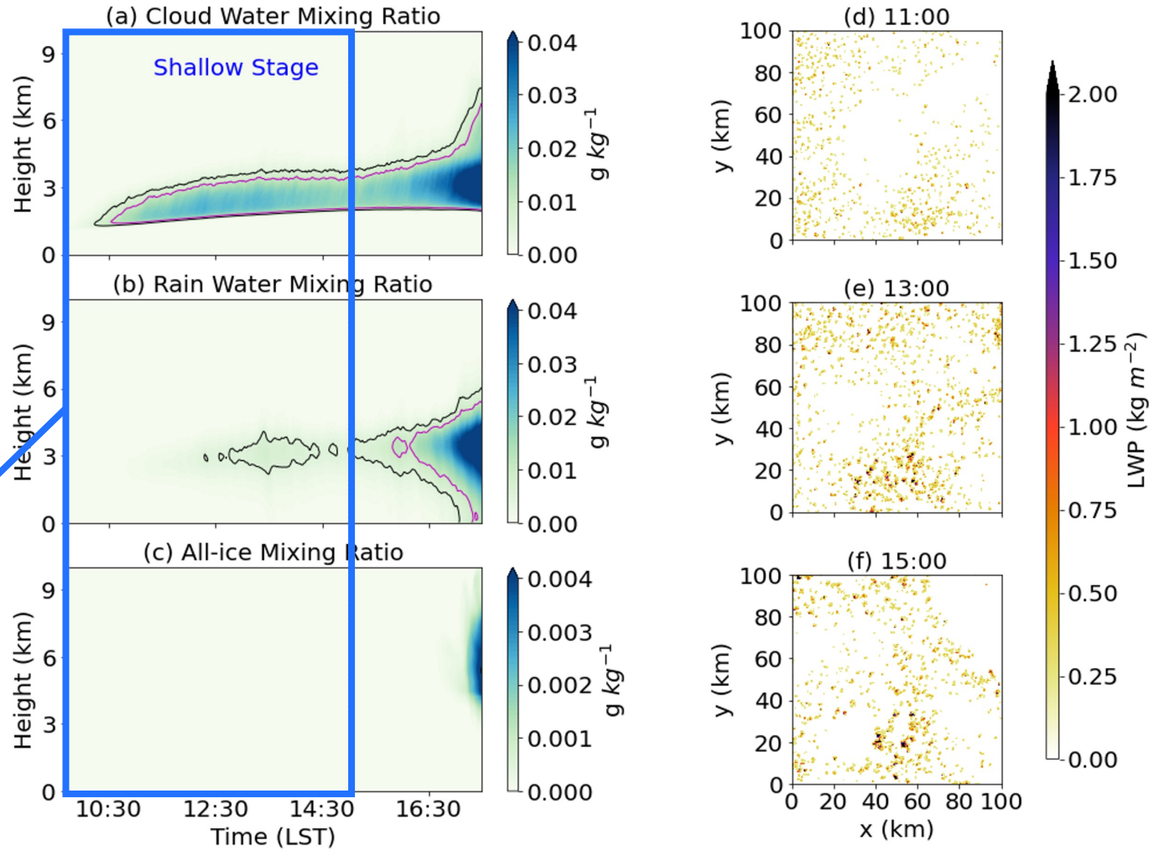
Subgrid cloud parameterizations are essential components in numerical earth system models as they account for the effects of unresolved cloud processes. Unlike mass-flux schemes assuming uniform cloudy areas, our proposed empirical model considers the non-uniform distribution of cloudy areas. Lotka-Volterra equation is used to derive the time tendency of cloud size based on ten thousand individual lifecycles of shallow cumulus clouds, based on a large-eddy simulation conducted during the Holistic Interactions of Shallow Clouds, Aerosols, and Land-Ecosystems (HI-SCALE) field campaign in the U.S. Southern Great Plains. With this model, we expect a more accurate representation of the cloud lifecycle in convective parameterization.

HI-SCALE Shallow Cumulus Case





Three stages



WRF-LES simulations
- 100m grid spacings
- 120x120km domain size
(Fast et al., 2019, Chen et al., 2022)

Questions?
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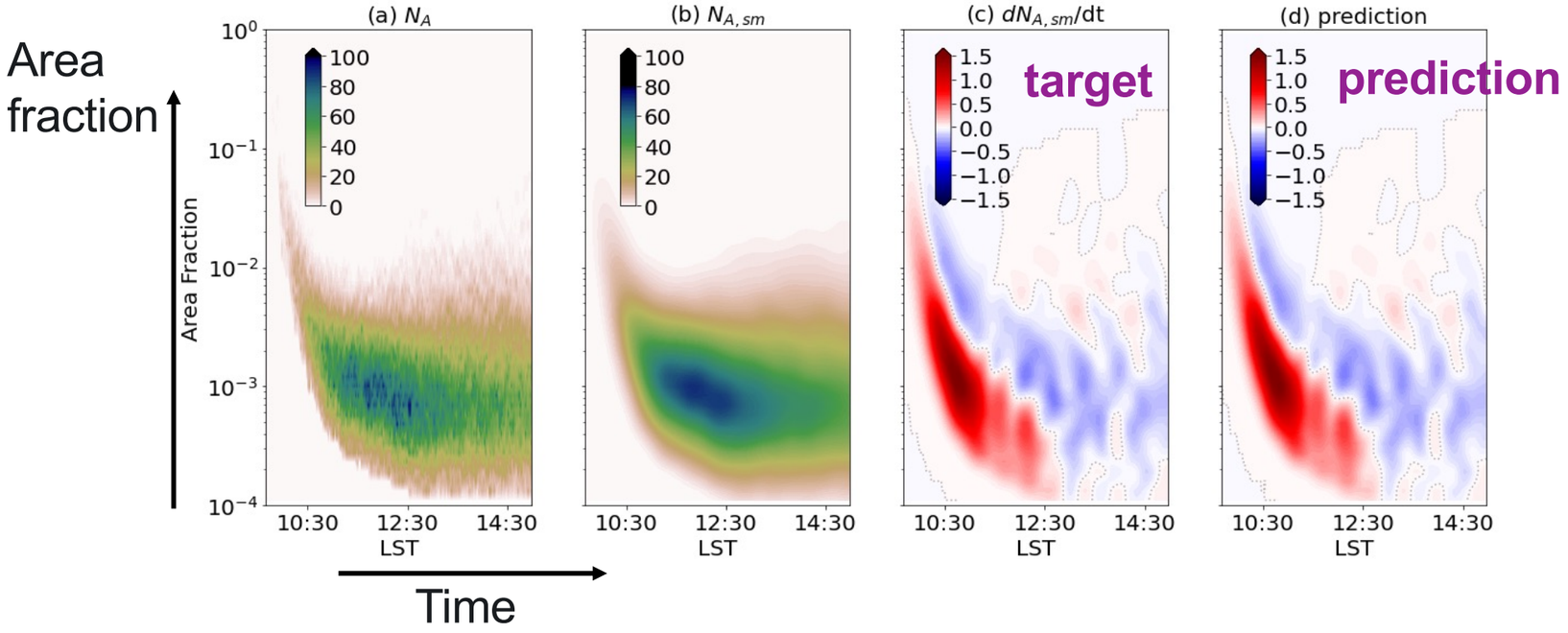
Predator-prey System for Cloud Growth

Cloudy area = total cloudy area × **area fraction**



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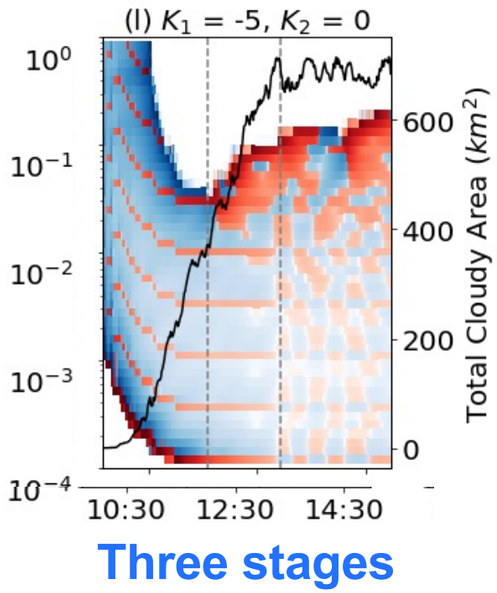

Three stages

Two species predator-prey equation:

$$\frac{dR}{dt} = R(c_1 - c_2F) = c_1R - c_2RF$$

$$\frac{dF}{dt} = F(c_3R - c_4) = -c_4F + c_3RF$$

R: prey

F: predator

Reducing the number of unknowns with prescribed parameter K_1 and K_2.

$$\frac{dN_i}{dt} = N_i \sum_{j=i+K_1}^{j=i+K_2} c_j N_j$$